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### TECHNICAL AREA

[001] The present invention relates to a sensor unit having a measured signal receiver,  
5 which registers a measured signal, an A/D converter connected to the measured signal  
receiver for digitizing the registered measured signal, and a transceiver device for  
wireless data transmission to and/or from an environmental device. The components  
cited are controlled using a processor. Furthermore, the present invention relates to a  
data communication system which comprises multiple sensor units of the cited type and  
10 an environmental device. In addition, the present invention also relates to an  
environmental device which is implemented for wireless communication (comprising  
transceiver operation) using at least one sensor unit of the cited type and in which an  
analysis unit is integrated or which may be coupled to an analysis unit.

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### BACKGROUND OF THE PRESENT INVENTION

[002] Sensors are used in a wide-ranging technical environment. Thus, for example,  
particularly in automation and processing technology, sensors are currently used for  
20 measuring process parameters such as fill level, pressure, temperature, etc. Actuators,  
such as valves, heating elements, or the like are used to influence the process  
parameters. According to the related art, the measured values determined by the sensors  
are analyzed by a process control system and the actuators are activated in order to be  
able to have the process run in the predefined process window. Since the sensors are  
25 often positioned at points of a manufacturing facility which are widely separated in  
space, wire-bound communication of the sensors with the process control system and  
with control and display units is often connected with a high cost outlay.

[003] As a result of this, efforts have been undertaken to implement the  
30 communication of the sensors with the process control system and with control and  
display units wirelessly, on the basis of the Bluetooth standard, for example.

DE 100 32 774 A1 describes a system in which field devices are wirelessly connected to a control and display unit for data input and display for process automation. According to this publication, the control and display unit is implemented as a separate portable unit. Furthermore, this publication discloses that the wireless connection is produced in accordance with the Bluetooth standard. According to one embodiment of DE 100 32 774 A1 cited, the field devices of a processing facility are exclusively connected wirelessly to a junction, which is linked via a data bus to the process control system. As a result, the field devices transmit the current measured values wirelessly to the process control system, which in turn activates the different actuators on the basis of the measured values.

[004] A system for wireless information transmission for multiple sensors and/or actuators on a machine is known from DE 199 33 814 A1. The known system comprises multiple users such as sensors or actuators and a base station. The base station preferably emits a broadband high-frequency signal produced according to the DSSS method. The users are located at different distances from the base station. The users code the high-frequency signal received according to the SDMA method, modulate it, and reflect it back to the base station. Signal correlation and demodulation is performed in the base station.

[005] The field devices or sensor units known from the related art have the disadvantage that each sensor unit is equipped with a processor which must assume both the tasks of controlling measured signal receivers, A/D converters, and interfaces, and also processing the measured signal. Processors which may assume these tasks are costly to provide and operate.

## DESCRIPTION OF THE PRESENT INVENTION

[006] According to a first aspect of the present invention, a sensor unit according to the present invention comprises a measured signal receiver which registers a measured signal. An A/D converter is connected to the measured signal receiver, which digitizes the registered measured signal. Wireless data communication to an environmental device is performed using a transceiver device, which is coupled to the A/D converter. A processor is provided in the sensor unit, which activates the measured signal receiver, the A/D converter, and the transceiver device in such a way that the registered measured signal is digitized and subsequently wirelessly transmitted directly via the transceiver device to the incremental device. According to a first exemplary alternative, this transmission device has an analysis unit which processes the digitized measured signal further into a measured value. A second alternative provides that the analysis unit is coupled to the environmental device, but is not an integral component of the environmental device.

[007] The present invention is based on the idea of providing a sensor unit which is cost-effective to manufacture and operate. In particular, by "outsourcing" the analysis of a measured signal from the sensor unit, among other things, in spite of the transceiver device to be operated, a low power supply is sufficient to supply the sensor with power. In particular, according to an exemplary embodiment of the present invention, power may then also be supplied via a 4-20 mA two-wire loop. As already noted, according to the present invention, the digitized measured signals are transmitted directly, i.e., without signal processing after the A/D conversion, via the transceiver device to the environmental device. Therefore, a powerful processor of a sensor unit known according to the related art, which assumes both control and also signal processing tasks, may be replaced by a smaller and less powerful and therefore more cost-effective processor, that particularly requires less power, which exclusively assumes control tasks.

[008] The signal processing of the measured signal received from the sensor unit is performed in an analysis unit which is housed in the central environmental device or is

connected thereto, by a powerful signal processing processor. When signal processing processors are discussed, this of course refers to a processor which may also assume control tasks in addition to signal processing. Furthermore, it is also conceivable, however, that the environmental device has a separate control processor and a separate signal processing processor. As a result, the one analysis unit of the environmental device may thus assume the signal processing of multiple sensor units. Each individual sensor unit is only equipped with a simple and cost-effective control processor in this case, the analysis unit having a complex and powerful signal processing processor.

10 [009] In summary, by using less powerful control processors, the manufacturing costs for a sensor unit and also its operating costs may be reduced, because of the lower power consumption of these processors, for example. A further advantage of the present invention is that using this arrangement, the computing time available is employed better. Because of the different cycle times of the sensors, idle time, i.e., time in which  
15 no computing power is necessary for data processing or for control, exists in sensor units having integrated signal processing. If the signal processing is assumed by a single analysis unit, the processor power for signal analysis may be adapted in accordance with the different cycle time requirements of the different sensor units, so that as a result nearly all of the available entire processor power is employed.

20 [010] In an exemplary embodiment of the present invention, the measured signal receiver, the A/D converter, and the transceiver unit each have a data input, a data output, and a control input. For this purpose, the data input the A/D converter is connected to the data output of the measured signal receiver and the data input of the  
25 transceiver unit is connected to the data output of the A/D converter. Furthermore, the transceiver unit exchanges data with the environmental device via its data output. In addition, the processor has an influence on the measured signal receiver, the A/D converter, and the transceiver device via each of the control inputs.

For this purpose, it is additionally to be noted that it is also possible to transmit configuration data or the like to a sensor unit via the environmental device, for example. A pure transmission device and also a transceiver device are thus to be subsumed under a "transceiver device" here.

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[011] According to a further exemplary embodiment, the sensor unit is a fill level sensor, using which the fill level of liquids in containers may be detected, for example.

[012] According to a further exemplary embodiment, the measured signal receiver of  
10 the fill level sensor transmits and receives a radar signal, an ultrasound signal, or a microwave signal guided on a wire, for example. The use of a guided microwave signal has the advantage that the container fill level may be measured locally.

[013] According to a further exemplary embodiment, the measured signal is a  
15 propagation time signal, the propagation time between emitting a reference signal and receiving one or more signals reflected from the liquid surface being analyzed.

[014] In a further exemplary embodiment, bidirectional data transmission occurs between the sensor unit and the environmental device having an analysis unit. Thus, a  
20 measured signal flow from the sensor unit to the environmental device and also a data flow from the environmental device to the sensor unit, in the form of control commands, for example, is conceivable.

[015] According to a further especially preferred embodiment, the wireless  
25 transmission of the data between the sensor unit and the environmental device having an analysis unit is performed in accordance with the WLAN standard, or the wireless personal area network standard, having multiple substandards such as Bluetooth, the HiperLAN 2 standard, DECT, the GSM standard, or the UMTS standard. Bluetooth technology will be discussed in this context as an example. Bluetooth technology is an  
30 open specification for wireless transmission of data and speech. It is based on a cost-

effective shortwave technology which may be implemented in a microchip and allows a secured ad hoc connection between fixed and mobile terminals. Bluetooth technology is on a broad platform of applications and was established as a standard in 1998 by Ericsson, Intel, Nokia, IBM, and Toshiba.

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[016] In a further exemplary embodiment, bidirectional data transmission occurs between the environmental device having an analysis unit and the process control system. Thus, for example, it is conceivable that the environmental device having an analysis unit is connected to the process control system wirelessly or via a wire. In particular, the wireless connection of the environmental device having a control unit to the process control system makes an especially flexible design of the entire system possible.

[017] In a further embodiment of the present invention, bidirectional data transmission occurs between the environmental device having an analysis unit and the process control system, the environmental device having an analysis unit transmits the generated measured values to the process control system, and the environmental device having an analysis unit receives control commands from the process control system.

[018] According to a further exemplary embodiment, the environmental device having an analysis unit is a mobile device. For this purpose, for example, it is conceivable that the environmental device having an analysis unit is integrated into a portable computer (laptop) or a PDA.

[019] According to a further exemplary embodiment, the sensor unit is wirelessly connected to a further environmental device, the further environmental device comprising a control and display unit. Through the wireless implementation of the connection between sensor unit and the environmental device having a control and display unit, the complex and costly wiring between the two devices is saved.

Furthermore, the operator may have an influence at various locations in connection with

the feature that the environmental device having a control and display unit is a mobile device, such as a portable computer. This means that an operator may move independently of the location of the sensor unit and, through the environmental device having a control and display unit, load data and parameters from the sensor and display  
5 and transmit them.

[020] According to a further exemplary embodiment, the environmental device having a control and display unit and the environmental device having an analysis unit are wirelessly connected to one another.  
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[021] In a further exemplary embodiment, bidirectional data transmission occurs between the environmental device having a control and display unit and the environmental device having an analysis unit. Thus, for example, it is conceivable for parameter data which is transmitted from an environmental device (for example, having  
15 a control and display unit) to the sensor unit to also be transmitted to the environmental device having an analysis unit, the environmental device having an analysis unit optimizing and adapting the parameter data to control commands from the process control system. The optimized parameter data thus obtained is subsequently relayed by the environmental device having an analysis unit to the environmental device having a  
20 control and display unit.

[022] A further possibility provided by the connection between environmental device having an analysis unit and environmental device having an operating and display unit is that the environmental device having a control and display unit may influence the  
25 environmental device having an analysis unit in such a way that algorithms which are used during the signal processing may be altered, tested, and optimized.

[023] In a further exemplary embodiment of the present invention, the sensor unit has a further transceiver device which communicates with the environmental device having a  
30 control and display unit. Through this feature, a separate transceiver device is available

in each case for the communication of the sensor unit with the environmental device having an analysis unit and with the environmental device having a control and display unit.

5 [024] Analogously to the wireless transmission of data between the sensor unit and the environmental device having an analysis unit, it is also advisable for the wireless transmission of data between the sensor unit and the environmental device having a control and display unit and/or between the environmental device having a control and display unit and the environmental device having an analysis unit if this transmission  
10 occurs according to one of the standards already cited above.

[025] In a further exemplary embodiment of the present invention, the analysis unit and the control and display unit are integrated into one single environmental device. A cost reduction may be achieved through the integration of the different components into  
15 one device.

[026] Furthermore, a data communication system, which comprises multiple sensor units, as were explained above, and an environmental device having an analysis unit, is also to be placed under protection. Consequently, multiple sensor units may be  
20 activated independently from one another and/or the measured signals received from these sensor units may be transmitted to the environmental device having an analysis unit by this data communication system. In the environmental device having an analysis unit, the different measured signals of the sensor units are processed further into measured values by the analysis unit in signal processing processes. The measured  
25 values produced are then transmitted to a process control system, for example, which controls the entire sequence of the manufacturing process of the production facility on the basis of these measured values.

[027] In a further embodiment, the data communication system also comprises an  
30 environmental device having a control and display unit. Therefore, using the



environmental device having a control and display unit, the different sensor units may be influenced independently of one another, without these sensor units being connected to the control and display unit via wires.

[028] According to a further aspect of the present invention, the present invention also  
5 relates to an environmental device which comprises a transceiver device that is  
implemented for wireless communication with at least one sensor device of the type  
described above. Furthermore, the environmental device comprises an analysis unit in  
which the measured signals wirelessly received from a sensor are analyzed and finally a  
value is generated which represents a measured value to be measured by the sensor and  
10 which may then be relayed to a display unit or even a control post, for example. This  
calculated measured value is then used for process control or displayed (such as fill  
level, temperature, pressure, flow volume, etc.). As an alternative to this exemplary  
embodiment of the present invention, the environmental device is not equipped with the  
analysis unit, but may be connected or coupled to an external analysis unit.

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### **BRIEF DESCRIPTION OF THE DRAWING**

[029] In the following, an exemplary embodiment of the present invention is described  
5 in greater detail with reference to the attached drawing for better understanding and  
explanation.

Figure 1 shows a block diagram of the sensor unit according to the present  
invention having an environmental device having an analysis unit and  
10 an environmental device having a control and display unit,

Figure 2 shows a block diagram of the data communication system according  
to the present invention,

15 Figure 3 shows a schematic flowchart of interoperability requirements for  
Bluetooth as a WAP transmission system for both a sensor according  
to the present invention and also a control unit,

Figure 4 shows a schematic flowchart for offline and online operation of the  
20 sensor according to the present invention, and

Figure 5 shows a schematic block diagram of multiple sensors A, B, and C  
having one or more environmental devices according to the present  
invention.

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### **DESCRIPTION OF AN EXEMPLARY EMBODIMENT OF THE PRESENT INVENTION**

[030] Figure 1a shows a sensor unit 1 according to the present invention, which is wirelessly connected to an environmental device 2 having an analysis unit 18 and to an environmental device 3 having a control and display unit 26, 27. The sensor unit 1 comprises a measured signal receiver 4 for registering a measured signal 9, an A/D converter 5 for digitizing the measured signal 9 and a transceiver device 6 for wireless data transmission between the sensor unit 1 and the environmental devices 2 and 3. Furthermore, the sensor unit 1 has a control processor 7 for controlling the measured signal receiver 4, the A/D converter 5, and the transceiver device 6. Parameters and calibration data necessary for the measurement sequence are stored in a memory 8. The control processor 7 has a direct influence on the memory 8 and calls parameters and calibration data from the memory 8 and/or writes them in the memory 8.

[031] In the present exemplary embodiment, the sensor unit 1 is a fill level sensor. The measured signal receiver 4 of the fill level sensor 1 transmits and receives a radar signal, an ultrasound signal, or a guided microwave signal, which are generally to be referred to as the measured signal 9, via a data input 31 for this purpose. The measured signal 9 may be converted from an ultrasound signal into an electrical signal in the measured signal receiver 4 for this purpose, for example. Subsequently, the measured signal 9 is output by a data output 10 of the measured signal receiver 4 and received by a data input 11 of the A/D converter 5 and digitized in the A/D converter 5. Subsequently, the digitized measured signal 12 is output by a data output 13 of the A/D converter 5 and received by a data input 14 of the transceiver device 6. The transceiver device 6 converts the digitized measured signal 12 into a radio signal 15 and outputs it via a data output 30. The radio signal 15 is received by a transceiver device 16 of the environmental device 2 having analysis unit 18. The transceiver device 16 again converts the radio signal 15 into a digitized measured signal 17, which is subsequently processed further into a measured value 19 in an analysis unit 18. The measured value 19 is output to a process control system 20 by the analysis unit 18 via possible further stations, which will not be discussed in this context. The process control system 20 in turn receives measured values 19 from greatly varying sensor units via the

environmental device 2 having analysis unit 18 (in Figure 1a, only the measured value 19 of the sensor unit 1 is shown). The different measured values are processed further in the process control system 20, i.e., the process control system 20 regulates the activation of actuators 29, 29', 29" on the basis of the different measured values 19 to  
5 influence the process and control of a manufacturing facility.

[032] The control of the measurement sequence by the measured value receiver 4 and the conversion of the analog signal by the analog and digital converter 5 and also the activation of the transceiver device 6 are assumed by the control processor 7. For this  
10 purpose, the control processor 7 is connected to the control inputs 21, 22, and 23 of the measured signal receiver 4, the A/D converter 5, and the transceiver device 6. Since the control processor 7 only assumes the activation of the measured signal receiver 4, the A/D converter 5, and the transceiver device 6, but not the analysis of the measured signal 9 and/or 12, high requirements are not placed on the performance of the control  
15 processor 7 in comparison to a signal analysis processor 28. This has the result that the control processor 7 is cost-effective to provide and operate.

[033] In order to exchange calibration data and parameter data for controlling the measurement sequence and operational status data between the sensor unit 1 and the  
20 environmental device 3 having control and display unit 26, 27, the environmental device 3 having control and display unit 26, 27 has a transceiver device 24. The transceiver device 24 communicates wirelessly with the transceiver device 6 of the sensor unit 1, through the Bluetooth standard, for example. In this way, status and parameter data 25 is transmitted between the sensor unit 1 and the environmental device 3 having control and display unit 26, 27.  
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[034] In order to optimize the signal processing, i.e., improve, test, and optimize parameters of the signal processing algorithms in accordance with the results from the signal processing, a wireless bidirectional exchange of control data 32 occurs between  
30 the environmental device 3 having control and display unit 26, 27 and the environmental

device 2 having analysis unit 18. In this way, it is ensured that the signal processing may be influenced using the environmental device 3 having control and display unit 26, 27 during the signal processing process. The exchange of the control data 32 is mediated via the transceiver device 24 of the environmental device 3 having control and display unit 26, 27 and by the transceiver device 16 of the environmental device 2 having analysis unit 18.

[035] Figure 1b has essentially the same features as Figure 1a, with the difference that an embodiment is illustrated in which both the analysis unit 18 and also the control and display unit 26, 27 are integrated into one single environmental device 33. The environmental device 33 also has a transceiver device 34, which exchanges non-analyzed measured signals 15 and status and parameter data 25 in the form of radio signals with the transceiver device 6 of the sensor unit 1. Furthermore, wire-bound control data 35 is exchanged between the control and display unit 26, 27 and the analysis unit 18.

[036] Figure 2 shows a data communications system, comprising three sensor units 1, 1', and 1'', each of which are wirelessly connected to an environmental device 2 having analysis unit 18 and an environmental device 3 having a control and display unit. In the present exemplary embodiment, the wireless data transmission is performed by both environmental devices 2, 3 according to the Bluetooth standard. Each sensor unit 1, 1', and 1'' emits radio signals 15, 15', and 15''. For this purpose, the radio signals 15, 15', and 15'' contain non-analyzed measured signals of the sensor units 1, 1', 1'', since analysis and signal processing occurs in the environmental device 2 having analysis unit 18. The environmental device 2 having an analysis unit transmits the measured values 19, 19', 19'' generated in its analysis device 18 to the process control system 20, which transmits control commands based thereon to actuators 29, 29', 29'' (and sensors).

[037] The parameterization and the status query of the sensor units 1, 1', and 1'' is performed through status and parameter data 25, 25', and 25'', which is exchanged

between the sensor units 1, 1', and 1" and the environmental device 3 having control and display unit 26, 27.

[038] Figure 3 shows, in a schematic and simplified form, the basic sequence in a control unit with and without sensor selection when the active device is the control unit. Furthermore, a case in which a sensor according to the present invention is used as the active device is also shown herein. The sequence described herein relates to the interoperability requirements when Bluetooth is used as the WAP transmission means between a sensor according to the present invention and a transmission device according to the present invention.

[039] Figure 4 illustrates the synchronization profile for communication between a sensor according to the present invention and an environmental device according to the present invention when Bluetooth is used. Figure 4 differentiates between online operation and offline operation. For further details, refer directly to Figure 4 and the flowcharts shown therein.

[040] Finally, Figure 5 schematically shows a block diagram of the communication between different sensors A, B, and C and environmental devices according to the present invention. It is thus obvious therefrom that, for example, a sensor A communicates with an environmental device and a display occurs in this environmental device in accordance with the analysis of the transmitted measured signal. Vice versa, the sensor A may also be operated via the operating device provided in the environmental device.

[041] In an alternative embodiment, sensors B or C perform a short-range transmission of measured signals, via Bluetooth, for example, to an environmental device. This environmental device then transmits the data in turn via modem over a long distance to a further modem, which is connected to a display. It is possible to perform the analysis in the environmental device, or to first perform the analysis in an analysis unit after the

long-range transmission of the measured signals. A measured value is only then accordingly displayed on and/or transmitted to a process controller.

List of reference numbers

	1	sensor unit
	2	environmental device having an analysis unit
5	3	environmental device having a control and display unit
	4	measured signal receiver
	5	A/D converter
	6	transceiver device
	7	control processor
10	8	memory
	9	analog measured signal
	10	data output (measured signal receiver)
	11	data input (A/D converter)
	12	digitized measured signal
15	13	data output (A/D converter)
	14	data input (transceiver device)
	15	radio signal (for example, non-analyzed measured signals)
	16	transceiver device (environmental device having analysis unit)
	17	digitized measured signal
20	18	analysis unit
	19	measured value
	20	process control system
	21	control input (measured signal receiver)
	22	control input (A/D converter)
25	23	control input (transceiver device)
	24	transceiver device (environmental device having a control and display unit)
	25	radio signal (status and parameter data)
	26	operating device
	27	display device
30	28	analysis processor



- 29     actuators
- 30     data output (transceiver device)
- 31     data input (measured signal receiver)
- 32     radio signal (control data)
- 5    33    environmental device having analysis unit, control and display unit
- 34    transceiver device (environmental device having analysis unit, control and display unit)
- 35    wire-bound signal (control data)